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Cellular Automata and their Applications: A Review

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ABSTRACT
In this paper author reports a detail study on the convergence of the one-dimensional two-state 3 neighborhood asynchronous cellular automata (ACA) under null theory.

General Terms
Asynchronous Cellular automata (ACA), Classification

Keywords
Convergence, fixed point attractor, multi-state attractor

1. INTRODUCTION
Cellular Automata (CAs) are among the oldest model of natural computing, dating back over a half century. The journey of cellular automata were originally proposed by Jon Von Neumann in the late 19400 s as formal models of biological self-reproduction, the goal was to design self-replicating artificial systems that are also computationally universal. The framework studied was mostly based on one and two dimensional infinite grids though higher dimensions were also considered. At the beginning, CAs were only focus on the concept of computer science and mathematics. However, gradually it is used in different fields such as Physics, Biology etc. In the present era, CAs are being studied from many widely different fields, and the relationship of these structures to existing problems are being constantly sought and discovered. A Cellular Automaton (CA) is a discrete dynamic system comprising of an orderly network of cell, where each cell is a finite state automaton. The next state of a particular cell is decided by its previous state and its neighbor's (left and Right most neighbor's) cells following a local update rule. Wolfram in [52] said that CA is an infinite 1-Dimensional, where each square box called a cell. In CA there are two possible state 1 and 0, where 1 is considered as black cell and 0 is considered as white cell. The next of each cell depends on the state of itself and its two neighbours (left and right). The CA cannot only model biological self-reproduction but also computationally universal. The beauty of a CA is simple local interaction and computation of cell results in a huge complex behaviour when the cells add together. Since the inception, CAs have captured the attention of a large number of researchers already working in this field as well as new entrants to this field. There are different variations of CAs which have been suggested by different authors to ease the design and modelling of Complex Systems. They are LinearCA, Complement CA, Additive CA, Uniform CA, Hybrid CA, Null Boundary CA, Periodic Boundary CA, Programmable CA, Reversible CA, Non-Linear CA, Generalized Multiple Attractor CA, Fuzzy CA.

Cellular automata are a collection of cells that each consists of a finite num- ber of states. Single cells change in states by following a local rule that depends on the environment (i.e., neighbor's) of the cell. The environment of a cell is usually taken to be a small number of neighbouring cells i.e., 1 or 2 neighbor's for 1-Dimensional as well as 2-Dimensional CAs [19]. Fig. 1. shows two typical neighbourhood options i.e., for 1-Dimension as well as 2-Dimension, (a) One Way CA (b) Two Way CA are 1-Dimensional CAs and (c) Von Neumann Neighbourhood (d) Moore Neighbourhood are 2-dimensional CAs. Basically, a cellular automaton (CA) consists of a graph where each node is a finite state automaton (FSA) or cell. This graph is usually in the form of a two dimensional lattice whose cells evolve according to a global update rule (CA Rule) applied uniformly over all the cells. As arguments, this update rule takes the cells present state and the states of the cells in its interaction neighbourhood (left and right most cells) [8] as shown in Fig. 2.

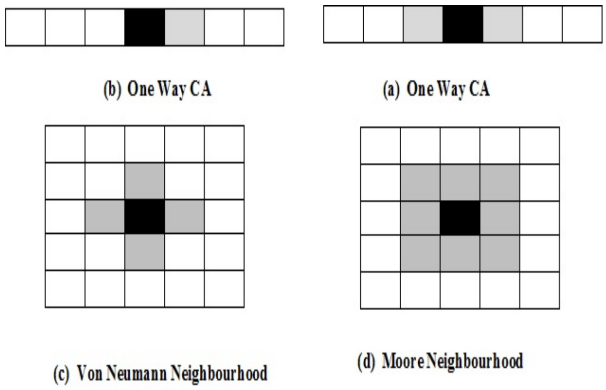

Fig. 1. 1(a) and 1(b) are 1-dimensional CAs, and 1(c) and 1(d) are 2-dimensional CAs

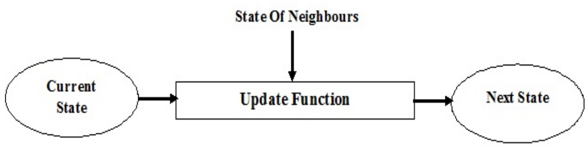

Fig. 2. State Transition depends on neighbourhood States.

Over the years, the computational model of CAs has been suggested to study the general phenomenological aspects including Communication, Construction, Growth, Reproduction, Competition and Evolution [22]. In the rest of this Paper we have discussed CA applied in different applications such as Image Processing, Fractals, Pattern Recognition and classification, Bio-Informatics, VLSI, Cryptography, The Games of life, Economic Systems, Biological Systems, Environ- mental Systems, Ecological Systems, Edge Detection, Traffic Systems, MachineLearning and Control, Crystallization Process and the like. In CAs [40][50], are defined by a lattice of cells and a local rule by which state of a cell is determined as a function of the state of its neighbour of length greater than 1 (multi-state attractors). The researchers have also classified the CA following their convergence property [55]. However, all such works have dealt with synchronous CA, where all the CA cells are updated simultaneously.

Among the huge applications of CAs, here we briefly discuss some of the applications of CAs such as Image Processing, Fractals, Pattern Recognition and classification, Bio-Informatics, VLSI, Cryptography.

This paper is coordinated as follows.The section I I consists survey about CAs in Image Processing, Section I II contains the survey report of CAs in Pat- tern Recognition and Classification, Section I V contain CAs in Fractal, Section V is detail about CAs in Cryptography, Section V I consists of CAs in Bioinfor- matics, Section V I I have review about CAs in VLSI, Section V I II displays the conclusion of this paper and Final section i.e., Section I X shows the Reference part of this paper.

2. CELLULAR AUTOMATAIN IMAGE PROCESSING

Over the last fifty years a variety of well known researchers such as John von Neumann, Stephen Wolfram and John Conway have explored the properties of cellular automata [32]. Particularly in the 19600 s and 19700 s significant activity was done towards developing special purpose hardware (e.g. CLIP) along-with developing rules for the application of the CAs to image analysis tasks. By the19900 s CAs could be applied to achieve a range of computer vision tasks, suchas: calculating properties of binary regions such as area, perimeter, convexity, gap filling and template matching and noise filtering and sharpening [32]. In this modern world parallel algorithms for solving any image processing task is a highly demanded approach. CAs are the most simple and common model of parallel computation. So, CAs have been successfully used in the domain of Image Processing for the last couples of years [31]. In Image Processing, the parallel algorithms are much more important than serial algorithms. Many standard algorithms for most of the Image Processing tasks have already been introduced by different researchers in the last few decades. But some researchers later have used CAs to solve the same problem and found to be better than conventional methods [31]. From this review it has been found that most of the researchers used Linear CA for solving different Image Processing tasks and very few of them using Hybrid and Non-Linear CA. Application of Hybrid CA and Non-Linear CA is a challenging task for researchers in this field. In CA, the states of the cells are updated synchronously at a discrete time step. So the time complexity to do any Image Processing task is the least.

In Image Processing mainly 2-Dimensional CAs are involved. The pixels of the images represent as cells of the CA and they update their state based on the states of the neighbouring cells (pixels). Multiple states of CA cells allow the processing of Grey Scale Images or Color Images. Identifying the rulesthat apply to cells in order to answer a certain request in Image processing in nether less a non-trivial task [4]. The simplest use of CA for Image Processing is given by the application of specific rules for different tasks of Image Processing, for example B-rule, 2-Cycles CAs, Totalistic Rule, Majority Rule, Linear Rule, Optimal Rule, Hill Climbing, Grow-Cut Algorithm, Seed Grow Cut Algorithm by Vezhnevets no different from Ford Bellmann Algorithm (That computes shortest paths from a cell to all other cells in the CA) and other methods such as Genetic Algorithm, Swarms Optimization, Genetic Programming and the like [4]. In particular, for filtering salt and pepper noise the CA performed better than Standard Median Filtering.

At the beginning the CA focus on the Binary Image Processing i.e., the image formed from 00 s and 10 s and gradually it moved to Digital Images and then Intensity Images. Digital Image Processing acting a vital tasks in daily life applications such as Satellite Television, Computer Tomography and Mag- netic Reverberation imaging also in the area of Research and Technology like Geographical Information Systems and Astronomy [35]. CA has been applied in Image Processing with various advantages in 1-D as well as 2-D CA. The increased number of cell states leads to a vast increase in the number of possible Rules. Therefore, a reduced intensity representation is used, leading to a three state CA that is more practical [35].

CA are successfully used in many Image Processing tasks including Image De- noising, Edge Detection, Image Compression, Segmentation, Geometric Trans- formation, Noise Filtering, Feature Detection and the like [4].

3. CA IN PATTERNRECOGNITION AND CLASSIFICATION

3.1 Cellular Automata Recognition:

Cellular Automata (CAs) are SpatioTemporal Discrete Systems (Neumann 1966) that can model Dynamic Complex Systems. For elementary pattern recognition a special type of Generalized Multiple Attractor Cellular Automata (GMACA) has been introduced. It is a promising pattern classifier using a simple local network of Elementary Cellular Automata (ECA) (Wolfram 1994) called at- tractor basin that is a reverse Tree Graph. For the Purpose of ordering the CA Rules GMACA utilizes a Reverse Engineering Technique and Genetic Algorithm (GA). This leads to a major disadvantage of Computational Complexity as well as Recognition Performance [41]. Due to the major drawbacks of Complexity and Recognition Performance stated previously, the binary CAs based classifier called Two-Class Classifier-GMACA with artificial point (2C2-GMACA) is presented. In [41] hence it is finally concluded that Two-Class Classifier GMACA with Ar- tificial Point (2C2-GMACA) for pattern recognition reports 99.98% recognition rate superior to GMACA which reports 72.50% when it is the case of Associative Memory. In case of Non-Associative Memory Two-Class Classifier GMACA with artificial point (2C2-GMACA) reports 95.00% superior to GMACA which re- ports 72.50%. So, Therefore Two-Class Classifier GMACA with Artificial Point7 to 14 times faster than GMACA. So in [41] suggest the extension of 2C2- GMACA to other pattern recognition tasks.

3.2 Cellular Automata Classification:

In [6] describes a pattern recognition method which will allow for a combination of approaches based on prior analysis and Contextual Information with those based on Artificial Neural Networks. [6] develop a new iterative Neural Network Skeleton or groundwork which allows the incorporation of Knowledge- Based reasoning in to the network topology. In order to solve any set of problems related to pattern recognition the Artificial Neural Networks (ANNs) is the simplest version, which proceeds by assigning positive and negative weights to links between processing nodes and then an appropriate algorithm is suggested. For Example, the Hop-Field Network can implement an associative memory of any input pattern. The Network can then recognize a given pattern, if the presented pattern is ”close” in some sense to one of the stored pattern. From the study of desirable features in a pattern recognition it arises a Neural Network implementation of a probabilistic CA (Cellular Automaton) and that has the following properties such as By the help of correlation and possible noise into a parallel iterative algorithm, integrates the information about the structure of the object to be recognized, As the connection are local: Only near by processors interacts etc [6].

Some Articles like [46] refers specialized class of 1-Dimensional CAs, called Linear/Additive CA which has gained the primary attention of many researchers as well as new entrants to this field. Many CAs applications were successfully developed by the utility of ease characterization Linear/Additive CA such as VLSI Design, Cryptography, pattern recognition etc. To get effective solution for pattern recognition it uses Multiple single -Length cycle Attractors around CAs which is more demand-able at the current work. For pattern recognizer, an appropriate scheme has been developed to sympathize the Single-Length Cycle Attractor CA, avoiding Multiple-Length Cycles [46].

The Internet-Worked society has been suffering a explosion of data that is acting as an barrier in acquiring knowledge. The meaningful perception of these data[58] is increasingly becoming difficult [1]. For the purpose of knowledge extraction, consequently Researchers, Practitioners, Entrepreneurs from diverse fields congregate together to develop sophisticated technique [1]. Study of data classification model form the basic of such research. A pattern classification normally comprises of two basic operations such as Classification and Prediction. The evolving CAs based classifier derives its strength from the different types of features. They are:

(a)To arrive at the derived model of CAs based pattern classifier a special class of CAs referred to as MACA is evolved with the help of GA [1].

(b)In the prediction phase the classifier is capable of accommodating noise based on distance metric [1].

(c)The classifier Employs simple computing model of three neighbourhood additive CAs having very high throughput that results in simple, regular, modular and local neighborhoods sparse network of CAs suits ideally for low cost VLSI implementation [1].

3.3 Background:

In [22] a special class of CAs has been focused referred as Fuzzy CAs (FCA) is employed to design the pattern classifier. FCA introduced in CAs more than 30years ago. It is a natural extension of conventional CAs which operates on Binary string employing Boolean Logic as next state function of a cell. For the purpose of analysis and synthesis of FCA a metric algebraic formulation has been developed. Extensive experimental results confirms the scalability of the proposed FCA based classifier to handle large volume of datasets[57] irrespective of the number of classes, tuples and attributes. The FCA based pattern classifier has established an excellent classification accuracy as an efficient and cost effective solution for the pattern classification problems. In [22] it is mentioned that FCA have been considered by several researchers in both theory and applications. By using rule supporting OR and NOR function as next state logic the FCA is configured.

In [18] a scalable evolutionary design for pattern recognition using Multiple Attractor CAs (MACA). By using Hamming distance based attractors MACA helps to impart Non-Linearity in the classifiers. In order to make the large classification problem involving Non-Linear boundaries method more scalable Isomorphism in MACA was exploited. In Satellite Image analysis problem the pattern classifier may be applied. Linear Classifier are not suitable for all problems. A data dependent non-linear metric is more versatile as it help in capturing and imparting non-linearity to classifiers inherently [18]. MACA is a special class of CAs that help us to lower the complexity by using Hamming Distance Metrics. Lowering the complexity has helped us in making the pattern classifier more scalable. The pattern classification have been utilized in many real life applications. The MACA classifier which is of great importance to the Data Mining Community. The current MACA based classifier shows a promise of simple bi- nary classifier and an inference mechanism on the dataset which can be used to solve many real life problems [18].

In [9] a theoretical skeleton has been improved to devise scheme for blending a Single Length Cycle Multiple Attractor CAs with the specific set of Pseudo- Exhaustive Bits (PE-Bits). In order to make a cost effective solution of real life applications and Multiple Single Length CAs with PE-Bits can be used. The said synthesized CAs is effectively utilized to design efficient pattern classifier [9].

In [23] the proposed classifier is designed around a special class of Sparse Network referred to as CAs which can be applied in their diverse field such as Data Mining, Image Compression and Fault Diagnosis. Data or Pattern Classification is the method of identifying common properties among a set of objects or data in a Database. It determines the objects into different classes. The essential requirements of developing the pattern classifier for current information age are high throughput and low storage requirements. Further, a low cost hard-wired for the implementation of such specific scheme is becoming very important criteria for on-line real time applications [23]. The various Conventional techniques developed for pattern classification are Bayesian Classification, Neural Network whose decision are too complex to meet such requirements. So, there is a pat- tern classifier built around a special class of Sparse Network which reduce the complexity of the CAs based algorithm from O(n3) to O(n) [23].

3.4 CA in Fractal:

The first fractals were discovered by a French Mathematician named ”Gaston Julia” who discovered them decades before the advent of computer graphics. Julia’s work was rediscovered by Benoit Mandelbrot Fig. 3.. The term ”Fractal” was coined by ”Benoit Mandelbrot” in 1975. The term Fractal is derived from the Latin word ”Fractus” which means ”Broken” or ”Fractured”. ”Mandelbrot Set” is most famous among all fractals. Basically a fractal is a ”Rough” or”fragmented” geometric shape that can subdivided into parts, each of which is at least approximately a reduced-size copy of the whole. This is one type of special property related to fractal called ”Self-Similarity”. A Fractal is a mathematical object that has two specific properties such as (a) Self-Similarity and (b) Chaos.

Fig. 3. Benoit Mandelbrot

(a) Self-Similarity: According to this property as you will break an Object or Image into small parts, you can able to see the original Object or Image over and over again in its parts i.e., when you look at a single sub-part it just look like the whole.

(b) Chaotic: Fractals are infinitely complex i.e., the object generated is complex in nature. Generally, Chaotic can be defined as: (1) Sensitive to Initial Conditions, (2) Topologically Mixing and (3) Dense Periodic Orbits. Amazingly, these beautiful complex objects are generated by using simple mathematical processes (rule) called CAs local rule. To know the fractal character of an object we have to check the dimension of the particular object i.e., the dimension of the object should not be an integer like 0, 1, 2, ... but it must be like 0.1, 1.2,

0.63....etc. A fractal often has the following special types of features such as:

(i) It has fine structure at arbitrarily small scales, (ii) To be easily described in traditional Euclidean Geometric Language, Fractal is too irregular, (iii) It is Self-Similar as well as Chaotic in Nature and (iv) It has simple and recursive definition.

Fractal Dimensions: Everyone knows the dimensions of a Line, Square, and a Cube and how they can be measured. They are One, Two and Three respectively. And, we can measure the Distance, Area, and Volume of those objects as well. However, what is the dimension of the inside of a Kidney or theBrain or Heart and do we measure their Surface Area, Volume etc? How about a piece of Cauliflower and other object with irregular shape? This is where fractal dimension can help us out. Fractal Dimension allow us to measure the complexity of a object as pattern wise measurement. There are two different types of fractal Dimension which is said in [16]. They are: a Self-Similarity Dimension. and b Box-Counting Dimension.

In recent years, CAs have been found of computing complex behaviour or system by using simple CAs local rule (Mathematical Processes) with local interaction. On simple initial configuration, the generated pattern might be Fractal or Self-Similar. Hence in [15] regular evolution of Totalistic Linear CAs is investigated i.e., Capable of generating fractal object or not. Based on Statistically observed long-term simple behavior CAs, Wolfram in [53] suggested a classification of CA. He discovered that the CAs appears to fall into four classes. Majority of CA rules falls in third class in which the evolution leads to a Chaotic Pattern. Not all the CA rule generate chaotic pattern even some of them generate Self- Similarity pattern or figure. Wilson has studied the generation of fractal pattern by additive CAS, that have Mod 2 addition (XOR) CA Local Rule, when the initial seed is single 1. In [15] shows the fractal behavior (i.e., Self-Similarity as well as Chaotic) of Linear Totalistic CAs as well as for Trellis Automata.

In [26] proposed a specific method to develop ”Fractal Pattern” by utilizing simple computation known as CAs. However, the problem of Fractal Pattern generation is done by using Linear CAS recently rather than Classical CAs. Here in [26] describe how to generalize cellular space of greater dimension by us- ing some basic techniques for the construction of the transition function, which draws a Cantor set. Then, further a specific method is developed for embedding the configuration into a closed interval to obtain fractal patterns. A sequence of error also appears by fractal during the transmission of data. The problem related to prove the fractal behavior of CAs is studied by Wolfram [53], Culik [15], Wilson [51] and Haesler et al. [10]. These authors often accord with linear modulo-2 uni-dimensional CAs whose main occasion is the Pascal Triangle, which can be developed finitely by algebraic means. Haesler et al. [10] claimed that the production of fractal pattern in the long time evolution of CAs poses three major problems such as: (1) When and in What sense for the evolution of CAS there is an limit-set? (2) How can the Self-Similarity feature of a limit-set be formally designed and deciphered? (3) Which class of CAs out of four class (According to Wolfram) of CAs can generate fractal structure? Therefore, where Wilson [51] discuss and solve the first problem, Takahashi [47] did it for second problem and Haesler et al. consider for all the three problems. In [26] introduce another specific method for the generation of fractal structure by involving CAs mostly based on Cantor Sets and Products of Cantor Sets (Example- The Sier- pinski carpet or Sierpinski-Menger Sponge). In [26] it work with an congregate of some configurations into a continuous space and we can restrict ourselves to a subsequence of the configurations in the discrete space to make computations. Hausdroff measure also an best method applied to generate Fractal Pattern using CAs.

3.5 CA in Cryptography:

The term ”Cryptography” has derived from a Greek word, which means ”Secrete Writing”. In the age of Global Electronic Connectivity to secure data storage and transmission against the possibility of message eavesdropping and electronic scam a basic technique is used which is called as ”Cryptography”. However,current global network are characterized by an very large growth of digital in- formation storage and transmission needs. Especially to promise security and authenticity in the field of electronic commerce transactions and for classified material many public and private organizations have become increasingly de- pend on cryptographic techniques. In [25] describes a single key cryptographic system based on One and Two-Dimensional CAs randomizers obtained by artificial evolution. CAs in cryptography was first introduced by Wolfram [54], and by Nandi et al. [38], Gutowitz [14], and Guan [13]. In [24] [25] [27] describes that the proposed encryption scheme is depend on the generation of Pseudo-Random Bit sequence produced by One and Two-Dimensional Non-Uniform CAs.

The basic objective of cryptography system is to secure the message that passing through an insecure medium. The security of data[59] is provided by the Cryptography Algorithms. The message to be sent over the insecure medium isknown as plain text, which is encrypted before sending over the medium. The encrypted message is called cipher text which is received at the other side and then it is decrypted back to the original plain text message. Cryptography is a mathematical process to perform encryption as well as decryption. Crypto- graphic algorithm with CAs is broadly classified into three categories such as : (a) Symmetric Algorithm, (b) Asymmetric Algorithm and (c) Authentication. In case of Symmetric Algorithm same key is used for encryption and decryption process, whereas for Asymmetric Algorithm different keys are used for encryp- tion and decryption process and for Authentication Algorithm mean that the receiver should be sure about sender identity. A CAs used in cryptography ia an organized lattice of cells and each cell have finite number of states such as

”True” (T) or ”False” (F). In [27] focused on security key for encryption and decryption with CAs as well as 256 bit CAs encryption and decryption is de- signed and synthesized. The CAs in cryptography is applied in different area such as Security, Defense, Medical, Business and Many other application Areas. The effective measure of cryptography Algorithm is how long it run encrypt and decrypt with out breaking the security key. in [3] it focus on symmetric algorithm where the sender as well as the receiver utilize the same key for encrypt and decrypt process. This key used by the sender to encrypt the message called as cipher text and then the same key is used by the receiver to decrypt the message called as plain text in order to get the original message [3].

Application of CAs in stream cipher cryptography was discovered by Wolfram [54] with Non-Linear CAs. In [38] describe the theory and application of additive CAs as the basic data encryption hardware module. For communication privacy or Concealment of data in data bank essentially required cryptography whose encryption may be achieved by building two types of ciphers such as Stream cipher as well Block cipher. A Block cipher is one in which the message is broken into successive blocks and they are encrypted or decrypted by a single key or multiple keys. On the other hand, in a stream cipher a message is broke into stream and then is encrypted by a key stream. In [38] present schemes for a class of Block cipher and Stream cipher around the regular structure of CAs.

Table 1. Table captions should be placed above the table

Graphics	Top	In-between	Bottom
Tables	End	Last	First
Figures	Good	Similar	Very well

3.6 CA in Bioinformatics:

Bioinformatics Encircle everything from data storage and recapture to the iden- tification and presentation of features within data, such as finding genes within DNA sequence, finding comparability’s between sequences, structural predictions. The proposed algorithm may be very much useful to solve many other Bio-informatic problems like Protein Structure Prediction, RNA Structure Pre- diction, Promoter Region identification etc. [33] aims at introducing a contemplate on the problem that can be easily addressed by CAs in Bioinformatics. The application of CAs in Bioinformatics is a virgin field in research out of the various existed algorithm introduced by different authors for addressing some problems in Bioinformatics. Till day none of the researchers has tried to track the major problems in Bioinformatics and find a common solution. In [33] provides information towards relating various problems in Bioinformatics logically and triesto attain a common structure for addressing the same. In [33] mainly focus on problem related to Bioinformatics like Protein Coding , Promoter Prediction, and Protein Structure Prediction. In [33] CAs is introduced with AIS-MACAs (Artificial Immune System based Multiple Attractor Cellular Automata).

Cellular Automata: Artificial Intelligence (AI) is the survey of impersonating human mental ability in a computer. Current AI methods most importantly focus on two general categories. They are: Explicit Modelling (Words, Images), Implicit Modelling (Numerical Techniques).

(a)Explicit Modelling: (Words, Images) This model has been successfully used in many domains based on rules, frames and case based learning. This model doesn’t have capability to handle unseen cases.

(b)Implicit Modelling: (Numerical Techniques) Based on perception and experience this methodology addresses this issue by advancement of the model dependent. And therefore, this model have capability to handle unseen cases because CAs based classifier can learn Associations.

(1) Cellular Automata: CAs consists of a grid of cells with each cell contain finite number of states. CAs is a computing model which afford a best platform to carry out complex computations with the available local information.

CA can be defined by four tuples (G, Z, N, F). where, G = Grids (Sets of Cells), Z = Set of possible cell states, N = Set which describe cells neighbor- hoods, F = Transition function (CAs local rule).

Basically, A CAs expose three basic characteristics such as : Locality, InfiniteParallelism, and Simplicity.

(i) Locality: CAs is defined by local interactions of its cells. The connectivity among the cells are defined on the basis of locality. Each cell can interact with the adjacent cells in which, the transitions derived between cells carry only small amount of data. None of the locally connected cells will have a global view of the complex system.

(ii) Parallelism: Most of the complex computing problem is demanded to address by parallel computing environment. In most parallel computers include more than a few dozen of processors. CAs can gain parallelism on a scale greater than massively parallel computers. On a spatially extended grid CAs performs its computations in a distributed fashion. It distinct from the conventional ap- proach to parallel computation in which a problem break into independent sub- problems, each sub-problem is being solved by different processor, the solution of each sub- problems are subsequently integrate to yield the final solution.

(iii) Simplicity: A cell is a basic unit of CAs that has a simple structure evolving in discrete time and space. A uniform CAs has been proposed and developed by Wolfram which is a significant benefaction in the field of computing. This leads to a One-Dimensional CAs which consists of cell with only Two-States answer Tree-Neighbourhood (Itself, Left most cell and Right most cell) and the current state of a cell depends on the state of neighborhood of a cell.

(2) Wolfram’s Two-state three neighborhood CAs: In Fig 4,5; display Wolfram’s two state and three neighbourhood CAs, which consists of 8 different possible

present state combination. [33] Presents Rule 254 for defining the transitions between the neighbors which is shown at Table 1.. Each CAs cell in he grid must be a memory element (D-Flip-Flop) with some combinational logic such as XOR and XNOR gate (Additive). The transition of each cell depends on the immediate neighbors.In CAs Rules plays an important role in developing a good classifier.

(3) AIS-MACAs (Artificial Immune System Based Multiple At- tractor Cellular Automata): Since thirty year ago a Multiple Attractor CAs which is special class of Fuzzy CAs has introduced. MACAs utilizes Fuzzy Logic to handle real value attributes. Genetic Algorithm (GA)structure is used to rep- resent the corresponding CA rule infrastructure. So [33] have named this special classifier as AIS-MACAs. AIS-MACAs can represent many problems in Bioinformatics.

There are different types of problems related to Bioinformatics which are focused by [33] such as: Protein Coding Regions, Promoter Region Prediction and Protein Structure Prediction. There is a special tool which is utilized for predicting Protein Coding and Promoter Region called as CAs based Integrated Tool [34].

Possible Combinations	Binary EquivalentofRule-254 (Next State)
111	1
110	1
101	1
100	1
011	1
010	1
001	1
000	0

Table 1. Rule Representation

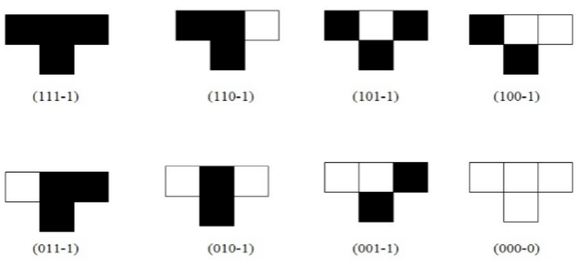

Fig. 4. Neighbourhood Representation

4. CELLULAR AUTOMATA-IMPLEMENTATION

Human body built up of lot of cells, each cell resides of Deoxyribonucleic Acid (DNA). But determining the coding regions is more complicated job compared to the former. Distinguishing the protein which absorb little space in genes is really a challenging task. In order to understand the gene coding region analysis plays a vita role [37][29].Proteins are molecules which has macro structure that are chargeable for a wide range of vital Bio-Chemical functions, which includes acting as Oxygen, Antibody Production, Nutrient Transport, Cell Signaling, and Building up Muscle Fibers. At current time Promoter Region Identification and Protein Structure Prediction has gained a remarkable attention. Even though there are few existing identification techniques addressing this problem where the approximate accuracy in recognizing the promoter region is closely 68% to

72%. But [37] have developed a tool that is based on CA build with Hybrid Multiple Attractor Cellular Automata (HMACAs) classifier for Protein Coding Region, Promoter Region Identification, and Protein Structure Prediction which predict the Protein Coding Region and Promoter Region with an accuracy of

76% as well as the Structure of protein with an accuracy of 80%. Bioinformatics is a concept that contains how to store data, Presenting the feature within the data[56] and retrieval of the data also.

The different type of Problems related to Bioinformatics are: (1) Protein Coding Region:

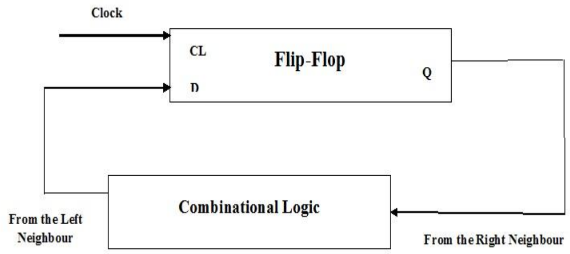

Fig. 5. Wolfram Representation of Flip-Flop Circuit

Genes hold the instructions for making proteins that are available in a cell as a specific sequence of nucleotides that are present in DNA molecules. In [29] introduce a unsupervised Fuzzy Multiple Attractor Cellular Automata (FMACAs) depends on pattern classifier to recognize the coding region of a DNA sequence. [29] propose a specific algorithm called as distinct K-Means Algorithm for de- signing FMACAs classifier which is simple , efficient and produces more accurate classifier than that of existed model been obtained for a range of various sequence length experimental result of handling large volume of dataset irrespective of the number of classes, tuples and attributes confirms that the scalability of pro- posed unsupervised FCA based classifier. By using distinct K-Means Algorithm [29] establish good classification accuracy.

(2) **Promoter Region Prediction:**

Determining the promoter regions plays an important role in understanding human genes. [45] Introduce a new CAs based Text Clustering Algorithm for

Captions should be Times New Roman 9-point bold. They should be numbered (e.g., “Table 1” or “Figure 2”), please note that the word for Table and Figure are spelled out. Figure’s captions should be centered beneath the image or picture, and Table captions should be centered above the table body.

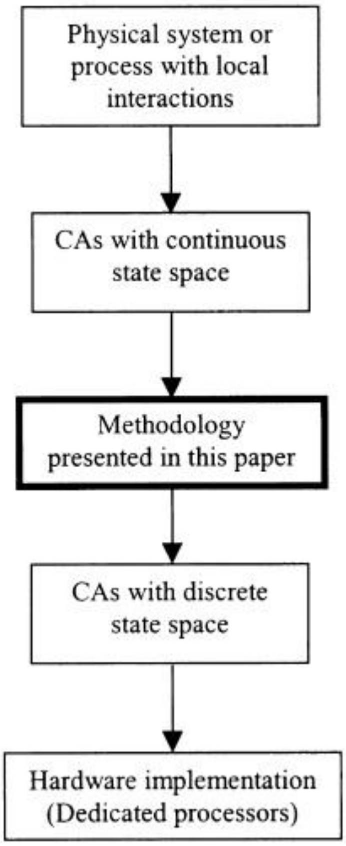

Fig.6.The methodology presented in this paper as a bridge between CAs as models for physical systems and processes (continuous state space) and CAs asa VLSI architecture (discrete state space).

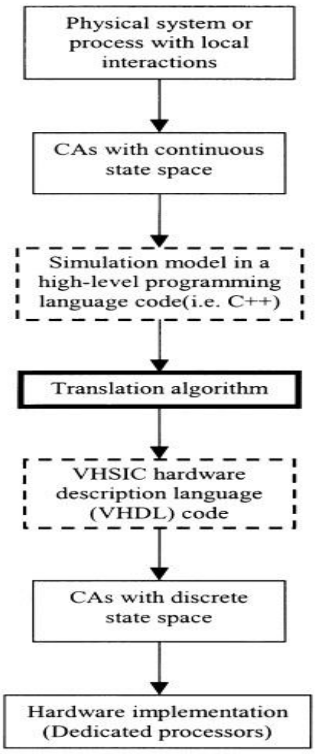

Fig. 7. The methodology proposed in this work built in a translation algorithm. The high-level programming language (i.e. C++) code is the input to this algorithm and the corresponding VHDL code is its output.

5. CA IN VLSI

VLSI stands for Very Large Scale Integration. [21] Summarize the basic characterizations of Two-Dimensional Cellular Automata (2DCAs) and its VLSI application. For One-Dimensional CAs various applications have been reported. On the other side 2DCAs is not yet a well-studied area. The system designers try to fix complex functions fromsoftware to hardware blocks on the silicon floors as the semiconductor technology is moving towards the sub-micron era. At the same time for keeping the design flexibility within a beneficial deadline, the designers are enforced to look for simple, regular, modular cascadable and reusable building blocks for achieving various complex function or behaviors. Therefore, CAs is a best platform that can able to fulfil all the above objectives. Moreover CAs successfully execute the demand for parallel processing architectures has gained importance with ever increasing needs for faster computing [21][2]. To this end [21] has motivated to consider the 2-Dimensional CAs to reach at the easily implementable parallel processing architecture in VLSI. Several researchers suggest VLSI applications of one-dimensional CAs one of the major contributions in this area is the BIST (Built in Self Test) framework of CALBO (CAs Based Logic Block Observer), which is analogous to the BIBLO framework designed around LFSR. It is hence proved that the pattern generated by one-dimensional model better randomness as compared to those generated by LFSR. In [21] it want to establish better randomness of the pattern generated by 2DCAs over that of1DCAs as a Pseudo-Random pattern generator was established.

[11] It has presented a preliminary prototype hardware employment of a 1- Dimensional Homogeneous Circle CAs system for generating CAs-based stream ciphers. The VLSI design was prototyped by utilizing theHardware Description Language (HDL) VHDL and synthesized to a Xilinx XC3S1000 FPGA. These hardware gives the probability of choosing the rule of the CAs being able to evolve over 3500 cells simultaneously.

[2] has proposed a VLSI architecture of CAs machine (CAM) based on mathematical model. There are various attractive applications of CAM in the fields of Image Analysis and Fractal Image Generation are also reported. This parallel architecture built around the CAM matches ideally for a variety of applications. A CAM has been introduced around the parallel architecture of 2DCAs . Such type of CAM can be economically built with the currently available VLSI technology. [12] has introduced for the first time a methodology for the VLSI implementation of CAs algorithm by using the VHSIC Hardware Description Language (VHDL). This approach builds a cross over connection between the CAs as models of physical systems and processes the CAs as a VLSI architecture. A translation algorithm is grown that has as input the CAs algorithms that simulate physical systems and processes and as output the corresponding VHDL code. The parameter of this translation algorithms are defined by the user and can be automatically summarized into synthesizable VHDL. The primary dissimilarity between CAs as models for physical systems and CAs as a VLSI architecture that depends on the CAs state space i.e., The state space of CAs that designs physical system is usually continuous , whereas the state space of CAs that are used as a VLSI architecture is discrete [12]. CAs as a VLSI architecture is shown in Fig. 6., which leads to the execution of CAs algorithms by dedicatedprocessors. VLSI circuits is used as implementation medium in order to implement these CAs algorithms in hardware, Synchronous. These implementations lead to a loyal processors that can be modelled using commercially available VLSI CAD systems (ex: CADENCE) Furthermore, the implementation of the algorithms could be achieved after the manual translation the parts of the algorithms, to become hardware into a synthesizable subset of a hardware description languages, such as Verilog or VHDL. In the present time VHDL is one of the most important and widely utilized hardware description languages and the application written in VHDL are increasing in size and complexity, promoting the use of parallel algorithm to achieve an acceptable simulation performance. In Fig 7. the CAs algorithms with continuous state space, applied to several physical systems, pro- cesses or other scientific problems are described as simulation models written in a high level programming language (i.e., C or C++). On the other hand, the dedicated processors appears from the above CAs algorithm, which have discrete state space and are implemented in hardware with the utilization of a hardware description language. The procedure proposed in this task is based on the translation of the high level programming language CAs algorithm, using VHDL. This procedure is diagrammatically presented in Fig 7. [12] has introduced a translation algorithm, which has its input the high level programming language code and generates automatically the VHDL code as its output code. Since the VHDL code is directly produced by the translation algorithm from the high level programming language code. So, no previous user knowledge of VHDL is required. The VHDL code thus achieved can be imported as input to a commercial VLSI CAD system, which will automatically generates the lay- out of the corresponding dedicated processor. As a result ofthis methodology, research workers may utilize widely available standard high level programming

[7] has proposed a technique to achieve expander graphs using CAs. The special class of CAs, called as the Two Predecessor Single Attractor Cellular Automata (TPSACAs) has been described. It has been demonstrated that the expander graphs assembled using the TPSACAs are encouraging and lead to the development of strong One-Way Function. [7] has introduced an efficient architecture for the One-Way function and implements it on an FPGA platform. Most of the extensively utilized key establishment algorithms engage One-Way function based on modular exponentiation that are computationally very expensive. However, the implementation of the introduced architecture by [7] displays that the TPSA based One-Way algorithm can be implemented very effectively with very less expenditure of computational resources like area and clock cycle. Such a type of One-Way function can be an ideal restoration of modular exponentiation based One-Way functions and thus help to expand fast and secure key establishment protocols. The achievement has been correlated with that of efficient implementation of modular exponentiation in GF (2m) and result present that the proposed One-Way function has a much superior VLSI implementation than a conventional One-Way function [7].

[36] has presented the study of One-Dimensional CAs exhibiting Group properties. The experimental results show that only a certain class of CAs rule models group characteristics based on rule multiplication. However, Many

other of these automata announce groups based on alternation of their global states. [36] has further shown how these groups may be used in the design of modulo arithmetic units. In order to map favorably to optimal communication graphs for VLSI layouts the communication properties of CAs are noticed. They accomplish the implementation medium and accurately address the physical limits on computational structures. Three major factors have resulted in the renewal of interest in the behaviour of Cellular Systems. First, the implementation of powerful computers and microprocessors have made feasible the rapid simulations of cellular automata in a serial, parallel and/or cellular mode of operation. Second, the utilization of CAs to simulate a various types of physical systems has gained much interest in the scientific community. And the final one is, the arrival of VLSI as an implementation medium has put attention on the communication requirements of successful hardware algorithms. In a recent survey of concurrent VLSI architectures, Scitz [42] has segregated the study of mesh algorithms for VLSI implementation several categories according to the granularity of the mesh. There is no confusion that two-dimensional CAs will potentially accomplish the VLSI technology in the best manner. A well knownexample of fine-grained 2-Dimensional CAs is Conway's "Game of Life" [5]. As a final tone, the systolic VLSI architectures of Thompson and Kung [48] may be considered as a medium-grained version of 1-D and 2-D CAs. The recent discussion is based on their importance in digital signal processing, matrix operations and related problems have been considered as the subject [36].

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